Orthopaedics & Traumatology: Surgery & Research (2010) **96**, 208—215

ELSEVIER MASSON
Available online at ScienceDirect www.sciencedirect.com
Elsevier Masson France EM|consulte www.em-consulte.com
Orthopaedics & Traumatology Surgery & Research

ORIGINAL ARTICLE

Shoulder hemi arthroplasty radiological and clinical outcomes at more than two years follow-up

X. Ohl*, C. Nérot, R. Saddiki, E. Dehoux

Maison Blanche Teaching Hospital Center, Department of Orthopaedic Surgery and traumatology, 45, rue Cognacq-Jay, 51100 Reims, France

Accepted: 7 January 2010

KEYWORDS
Shoulder;
Osteoarthritis;
Avascular necrosis;
Prosthesis;
Radiology;
Resurfacing

Summary
Introduction: Humeral head replacement is used for glenohumeral osteoarthritis in young or active patients, for conditions sparing glenoid cartilage or when glenoid implantation does not appear feasible. These surgical procedures usually give satisfactory results but there is a risk of glenoid erosion and a possible deterioration of long-term outcomes.
Hypothesis: There is a risk of glenoid erosion after humeral head replacement which can be radiographically measured. The importance and progression of this erosion should be evaluated to determine its clinical relevance.
Patient and methods: This is a retrospective study in 15 patients (19 shoulders) who underwent humeral head replacement between 1999 and 2006. There were 11 women and four men with an average age of 54.5 years. Etiologies were avascular necrosis (11 cases) and glenohumeral osteoarthritis (eight cases). All patients were reviewed in 2008 with more than two years follow-up. Clinical evaluation included measurements of range of motion and determination of the Constant and Murley score. In addition, the patients were asked to provide a subjective evaluation of their shoulder. Radiographic analysis included computer-assisted measurements.
Results: The average follow-up was 45.8 months (26—108). At one year postoperative and at the final follow-up, clinical parameters such as the Constant and Murley score (37.4/100 preoperative to 64.4/100 at final follow-up) were significantly increased. During the first year, the rate of glenoid wear was 1.03 mm/year in case of avascular necrosis and 0.27 mm/year in case of osteoarthritis ($p < 0.001$). Glenoid depth at the final follow-up was 6.97 mm for osteoarthritis compared to 4.59 mm for avascular necrosis ($p < 0.01$). We did not find any correlation between glenoid erosion severity and clinical results.

* Corresponding author. Tel.: +00 333 26 78 76 67.
E-mail address: xohl@hotmail.com (X. Ohl).

doi:10.1016/j.otsr.2010.01.001

Discussion: Isolated humeral head replacement may result in glenoid erosion. The rate of progression of this erosion is clearly influenced by the etiology and therefore by the preexisting condition of the glenoid cartilage. At the average follow-up, the radiological glenoid deterioration is not correlated with pain or deterioration of clinical results.
Level of evidence: Level IV. Therapeutic study.

Introduction

Simple humeral arthroplasty which was initially described by Neer to treat fractures of the proximal humerus [1], is now indicated not only in traumatic cases, but also for degenerative or rheumatic diseases as well as in cases of avascular necrosis.

Treatment of these entities by humeral head replacement has already been shown to be clinically effective for reducing pain and improving mobility, activity and muscular strength. [2—8]. However, there is risk of glenoid erosion with this procedure, similar to that described in hemiarthroplasties of the hip or acetabular cup revision [9]. Glenoid wear due to friction from the metal component is confirmed by glenohumeral joint space narrowing and by an increase in glenoid depth. Resulting pain seems to be the origin of most surgical revisions after hemiarthroplasty [10].

In our experience, certain patients present with radiographic control results showing signs of glenoid erosion while the clinical results are completely satisfactory. Our hypothesis is that radiological glenoid wear is present after humeral head replacement. This wear can be measured radiologically, and is not always associated with poor clinical results.

To confirm this hypothesis, we performed a retrospective study with more than 2 years of follow-up in humeral head replacements performed in our unit and we analyzed all clinical and radiological parameters preoperatively, at 1 year and at a final follow-up.

Patients and methods

Inclusion criteria

Between May 1999 and April 2006 with more than 2 years of follow-up, 21 consecutive patients (25 shoulders) with primary or secondary centered glenohumeral osteoarthritis or avascular necrosis of the humeral head without glenoid deterioration, underwent simple humeral arthroplasty with no glenoid surgery. For the purpose of etiological homogeneity, arthroplasty for fractures, which includes the problem of tuberosity reconstruction, or in cases of rheumatoid polyarthritis whose articular and periarticular characteristics and articular deterioration are very specific, were excluded from the study. The indication for surgery was decided for each entity after appropriate medical treatment had failed, in the presence of persistent functional difficulties and pain.

Patients who were included underwent a clinical follow-up review in 2008 and had a complete good quality radiological workup permitting evaluation of disease progression. Thus, 15 patients (19 shoulders) were included, 11 women and four men, an average of 54.5 years old (range 42—79). There were 11 avascular necroses of the humeral head and eight glenohumeral osteoarthritis. The Cruess classification was used to define the stage of avascular necrosis [11]. For centered glenohumeral osteoarthritis, the glenoid cavity was evaluated on the axial plane using the Walch and Badet classification [12]. Finally, the Favard and Sirveaux classification [13] was used to evaluate the glenoid cavity in a frontal view in all patients. All data are presented in Table 1.

Surgical procedure

All procedures were performed by the same senior surgeon (CN) under general anesthesia associated with an interscalenic block. The patients were in a beach-chair position and the deltopectoral approach (12 cases) or the anterolateral approach (7 cases) was used. Rotator cuff quality was evaluated preoperatively then confirmed during surgery: in three cases, there was a simple transfixing lesion of the supraspinatus muscle tendon; these lesions were treated with transosseous reattachment.

The tendon of the long head of the biceps was preserved in nine cases. In nine other cases, the proximal biceps was resected and tenodesis of the remaining part was performed with transosseous non-resorbable sutures, at the level of the bicipital groove. Finally, one patient presented preoperative rupture of the long head of the biceps.

Replacements were anatomical humeral prosthesis in six cases (Anatomical Shoulder™: Zimmer, Winterthur, Switzerland) or resurfacing prosthesis in 13 cases (six Copeland™: Biomet, Warsaw, Indiana between 2003 and March 2005 and seven Global Cap™: Depuy, a Johnson and Johnson company, Warsaw, Indiana since March 2005) (Table 1).

In cases of glenohumeral osteoarthritis, simple humeral head replacement was performed instead of a total shoulder replacement either because the patient was young in three cases (42, 44 and 58 years old), or in five cases because glenoid replacement was not technically possible due to insufficient bone stock and/or because dysplastic or degenerative retroversion was too significant (average retroversion in these patients was $23.3^{\circ} \pm 4.5$ vs an average retroversion of 6.4° in young patients).

Clinical evaluation

Clinical data were obtained preoperatively, 1 year postoperatively, and during a final follow-up at least 2 years after surgery. Data included evaluation of active range of motion, muscular strength and calculation of the Constant score and the weighted Constant score [14—16]. Subjective evaluation of surgery was obtained from the patient by asking him/her to note his/her satisfaction using the Subjective Shoulder Value (SSV) index from 0 to 100 points [17].

Table 1 Detail of indications, radiological and clinical follow-up parameters.

No. of patient	Sex/age	Etiology		Favard & Sirveaux Classification [13]	Follow-up (months)	Type of prosthesis/RC prosthesis (mm)	Variation offset (mm) (postop − preop)	Constant score follow-up (weighted)	Joint space follow-up (mm)	GD follow-up (mm)
		AVN [11]	OA [12]							
1	F/47	III		E0	28	Global Cap™/22.0	−1.2	70 points (82%)	2.0	3.4
2	F/53	II		E0	46	Copeland™/25.0	+2.5	79 points (95%)	1.8	4.7
3	F/54	II		E0	36	Copeland™/25.0	+10.0	89 points (107%)	1.2	3.6
4	M/49[a]		C	E0	29	Global Cap™/26.0	+2.1	56 points (62%)	0.7	8.1
5	M/42		A1	E0	49	Copeland™/26.9	+4.2	95 points (102%)	0.5	7.0
6	M/58[b]	II		E0	28	Global Cap™/26.0	+2.1	37 points (41%)	1.0	5.0
7	F/49	III		E0	27	Global Cap™/22.0	+1.2	57 points (69%)	2.3	4.6
8	M/46	III		E0	29	Global Cap™/26.0	−1.1	86 points (92%)	2.9	7.5
9	F/55		B2	E1	42	Copeland™/25.0	−1.2	60 points (72%)	0.2	6.0
10	F/57		B2	E1	26	Global Cap™/22.0	−1.3	81 points (98%)	0.4	5.2
11	F/44		A1	E0	43	Copeland™/25.0	+6.5	48 points (56%)	0.3	3.6
12	F/61	IV		E0	67	Anatomical Shoulder™/24.3	+2.5	50 points (61%)	0.6	2.9
13	F/62	III		E0	59	Anatomical Shoulder™/24.3	+9.0	50 points (61%)	0.9	4.2
14	F/53	II		E0	57	Anatomical Shoulder™/24.3	−2.4	77 points (93%)	0.5	4.3
15	F/53		B1	E0	57	Copeland™/25.0	+4.0	21 points (25%)	0.4	8.9
16	F/56		B1	E1	29	Anatomical Shoulder™/23.4	+5.0	78 points (94%)	0.5	10.4
17	F/58		B1	E0	35	Global Cap™/22.0	−1.1	74 points (90%)	0.2	6.6
18	F/79	II		E0	108	Anatomical Shoulder™/26.0	+6.7	63 points (79%)	0.4	6.5
19	F/60	II		E0	76	Anatomical Shoulder™/22.6	+3.8	51 points (62%)	0.8	3.8

AVN: avascular necrosis; OA: centered glenohumeral osteoarthritis; RC: radius of curvature; GD: glenoid depth.

[a] Patient presenting with postoperative algodystrophy.

[b] Patient who developed a deep infection requiring surgical debridement.

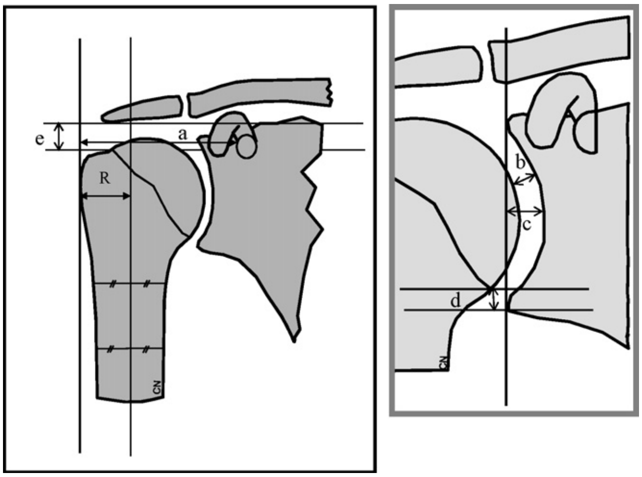

Figure 1 Illustration showing the different radiographic parameters studied. *R* = reference distance, *a* = glenohumeral lateral offset, *b* = joint space, *c* = glenoid depth (GD), *d* = proximal migration (pM), *e* = subacromial space.

Radiographic evaluation

We used a strict radiographic protocol with pre- and postoperative fluoroscopic X-ray including an anteroposterior view in neutral rotation, a lateral view and an axillary view. In 15 cases, a CT scan (simple or associated with arthrography) or MRI completed the preoperative workup.

Critera for success in the anteroposterior view with the shoulder in neutral rotation were:

- clear glenohumeral joint space;
- clavicle and the acromion superimpose;
- scapulohumeral girdle intact;
- lateral view of the great tuberosity.

The lateral view was performed with a posteroanterior and horizontal beam and the criteria for success were:

- strict profile of the scapula;
- scapula completely visible;
- glenoid and humeral head superimposed.

For the axillary view, the X-ray beam was positioned vertically from above to below allowing good visualization of the anterior and posterior glenoid rims as well as the body of the scapula.

All X-rays were computerized then scaled to size using the real curve of the beam of the prosthesis as a reference for postoperative films. To scale the preoperative films to size, we used a reference distance ''*R*'' corresponding to the offset of the great tuberosity which remained constant between the pre- and postoperative evaluation [18]. Measurements of anteroposterior X-rays in neutral rotation were obtained using MetrOs© (v 4.0 F) software, (Fig. 1):

- **lateral glenohumeral offset (*a*)** was defined as the distance between the lateral edge of the greater tuberosity and the base of the coracoid process [19];
- the region of interest of the **glenohumeral joint space (*b*)** was the region where this joint space was the narrowest between the prosthesis and the glenoid. Three successive measurements were taken in this region of interest according to the technique described by Parsons et al. [20] so that the average value could be calculated;
- Glenoid Depth was evaluated by the **distance ''GD'' (*c*)** measured between the center of the glenoid and the line passing by the upper and lower glenoid rims [21];
- the proximal migration of the humerus in relation to the glenoid was measured by the **distance ''pM'' (*d*)** defined as the distance between the horizontal line passing by the lower glenoid rim and the horizontal line passing by the humeral head implant *d* [21];
- **the subacromial space (SAS) (*e*)** was determined by the distance separating the upper edge of the greater tuberosity and lower cortex of the acromion.

Centering of the humeral head on the sagittal plane was determined either by CT scan [12], axillary view [22] or by lateral view. The humeral head was then qualified as centered or with posterior or anterior subluxation.

Statistical tools

The statistical evaluation was performed with Epi Info© v3.4 software (Chi^2 test and Fisher test for qualitative data and ANOVA and Kruskal-Wallis for non-qualitative data).

Results

Clinical results

The average delay before the final follow-up was 45.8 months (26—108). There were no complications during surgery. One patient presented with a deep infection; another with algodystrophy. Pain was markedly reduced 1 year after surgery and at the final review. Range of motion was significantly improved both one year after surgery and at the final review. ($p < 0.05$) (Table 2).

In the preoperative evaluation, 84% of the shoulders (16 patients out of 19) presented with internal rotation deficits (at the level of the buttocks or the lumbosacral junction). At one year, 68% (13 out of 19) patients could reach the 12th thoracic vertebra (D12) and 58% (11 out of 19) patients at final review.

The Constant score and its subunits were significantly increased at 1 year and remained stable at the final follow-up (+26.9 points at 1 year +27.0 points at the final review for the Constant score) (Table 3).

Clinical outcome was not significantly influenced by the criteria of age, sex, initial etiology, type of prosthesis or the presence of rotator cuff injury.

At the final follow-up, the average SSV of the patient for the operated shoulder was 74.6 ± 19.9 points out of 100 and the surgical results were qualified as excellent in 11 cases, good in six cases and poor in two cases.

Table 2 Changes in clinical parameters.

	AAE	ALE	ER1	ER2
Preoperative	106° (± 31)	90° (± 29)	30° (± 18)	45° (± 30)
1 year	153° (± 25)	131° (± 28)	37° (± 14)	70° (± 15)
Final follow-up	136° (± 30)	121° (± 35)	46° (± 12)	70° (± 20)

AAE: active anterior elevation; ALE: active lateral elevation; ER1 and ER2: external rotation 1 and 2.

Table 3 Changes in the Constant score and its subunits.

	Constant /100	Constant weighted	Pain /15	Activity/20	Mobility /40	Strength
Preoperative	37.4 (± 12)	43.9% (± 14)	3.2 (± 2)	11.2 (± 2)	18.7 (± 6)	4.3 points (± 4)
1 year	64.3 (± 12)	75.9% (± 14)	9.7 (± 3)	15.3 (± 2)	30.8 (± 6)	8.5 points (± 4)
Final follow-up	64.4 (± 19)	75.8% (± 22)	9.5 (± 5)	16.8 (± 3)	29.8 (± 8)	8.3 points (± 6)

Radiological results

The average preoperative lateral glenohumeral offset was 41.8 mm. This was significantly increased by an average of 2.7 mm (±3.6) ($p < 0.004$) on immediate postoperative films. No factors were found to influence the increase in offset, whether it was the type of prosthesis (simple humeral replacement or resurfacing replacement), etiology, association of a biceps tenotomy or associated rotator cuff injury.

The average immediate postoperative joint space was 1.92 mm ± 1.27. In cases of glenohumeral osteoarthritis, it was 0.87 mm, while for avascular necrosis it was 2.69 mm ($p < 0.001$). The rate of glenoid wear during the first year was 1.03 mm/year in case of avascular necrosis and 0.27 mm/year in case of glenohumeral osteoarthritis ($p < 0.001$). Between 1 year after surgery and the final review, glenoid wear progressed less rapidly and was 0.24 mm/year for avascular necrosis and 0.10 mm/year for glenohumeral osteoarthritis ($p = 0.7$) (Fig. 2).

The average immediate postoperative glenoid depth (Table 4) was 4.33 mm and it was not influenced by the initial etiology. At the final follow-up, glenoid depth and the rate of glenoid wear differed according to the initial etiology; 87% (seven out of eight) patients with glenohumeral osteoarthritis presented with significant glenoid wear (> 0.5 mm) compared to 36% with avascular necrosis (four patients out of 11) (Fig. 3).

Change in offset, the type of replacement, the presence of a tenotomy or associated rotator cuff injury did not influence changes in glenoid depth or joint space in this study population.

There was a significant reduction in the subacromial space from 12.9 mm to 11.28 mm ($p < 0.03$) at the final follow-up which was associated with an increase in proxi-

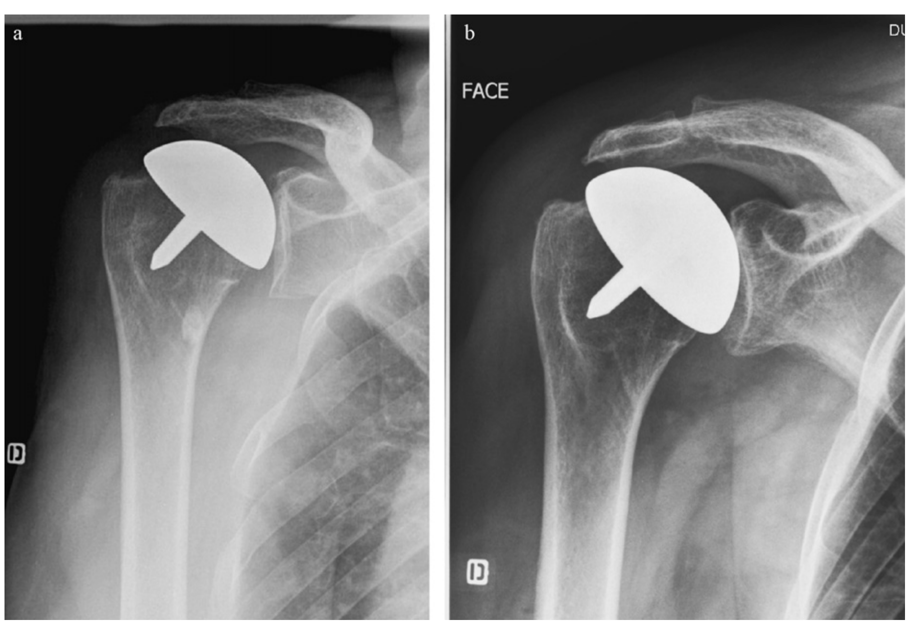

Figure 2 47-year-old woman, humeral resurfacing for avascular necrosis. Glenoid wear (a) between postoperative radiography and (b) final follow-up at 28 months.

Table 4 Rate of progression of glenoid depth over time.

	Glenohumeral osteoarthritis	Avasclar necrosis	p-value
Postoperative GD	4.64 mm (±1.7)	4.10 mm (±1.0)	$p = 0.39$
GD at final follow-up	6.97 mm (±2.2)	4.59 mm (±1.3)	$p < 0.01$
Average rate of increase in GD over time at final follow-up	0.75 mm/year	0.10 mm/rate	$p < 0.01$

GD: glenoid depth.

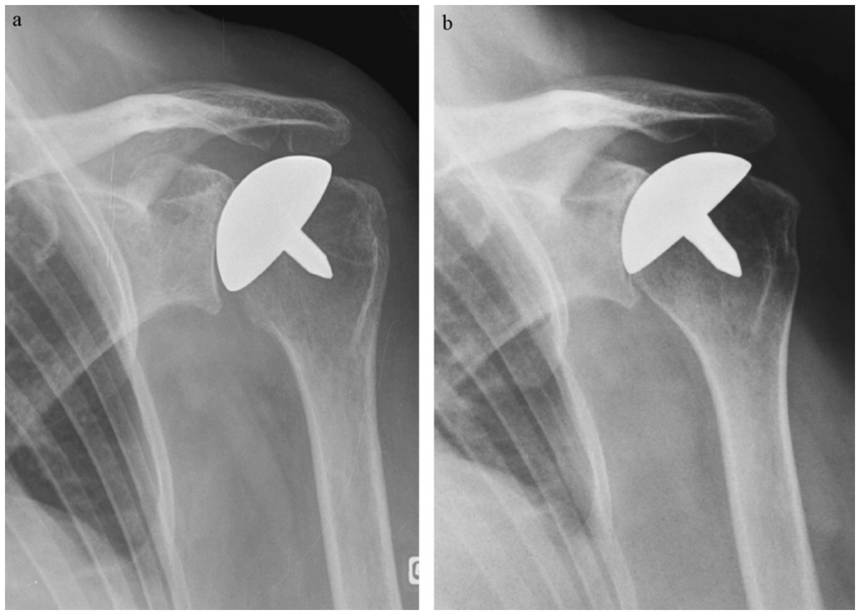

Figure 3 57-year-old woman, humeral resurfacing for primitive osteoarthritis. Increase in the glenoid depth (a) between postoperative radiography and (b) final follow-up at 26 months.

mal migration ''pM'' from 1.60 mm to 3.80 mm ($p < 0.01$). In our series, this humeral head migration was not influenced by any of the following parameters: type of replacement, association with preoperative rotator cuff injuries, associated biceps tenotomy, age, delay to final follow-up. This reduction of the SAS was not associated with poorer clinical results.

In the preoperative evaluation, the humeral head was centered in the sagittal plane in 14 cases, and presented with anterior subluxation in five cases (four cases of glenohumeral osteoarthritis and one case of avascular necrosis). At the final follow-up, the head was centered in 13 cases and presented with posterior subluxation in six cases (five cases of glenohumeral osteoarthritis and one avascular necrosis) There was no statistical relationship between the quality of anteroposterior centering and glenoid wear or clinical outcome, despite the different etiologies.

Discussion

The aim of this study was the evaluate glenoid wear after simple humeral head replacement using a strict protocol of radiographic measures and compare them to clinical data.

An analysis of clinical parameters showed that humeral head replacement resulted in significant and stable improvement of subjective and objective clinical criteria, which were not influenced by different etiology, type of replacement or the presence of limited rotator cuff lesions. Thus, at the final follow-up, 89% of patients were satisfied with the humeral head replacement, (good or excellent results). Our results are comparable to those found in the literature for clinical scores and joint range of motion, whatever the etiology. [4—6,8,23,24].

Our results suggest that the main element to take into account when estimating glenoid wear after humeral head replacement is etiology.

Radiographic narrowing of the glenohumeral joint space occurred in all our patients in this series over time while the prevalence of wear in the literature varies between 58 and 100% [5,6,10,20,25]. The rate of joint space wear was significantly higher in the first year in patients with avascular necrosis than in those with glenohumeral osteoarthritis. After the first year, there was no difference between the two groups. Similar results can be found in the literature, for example, the study by Dalldorf et al. showed a linear and proportional relationship in the hip between acetabular cup cartilage deterioration and the duration of the hip replacement [9]. In a study by Cruess et al. on hemiarthroplasties of the healthy hip in the dog, there was no remaining healthy cartilage six weeks after hip replacement and severe cartilage wear had developed after six months leaving the bone exposed [26]. Most of our results are also comparable to the study of Parsons et al. in 2004 [20], which evaluated glenoid wear in eight hemiarthroplasties in young patients (< 60 years old), with a supposedly healthy glenoid and intact rotator cuff (seven out of eight cases were post-traumatic). Glenoid erosion was found in 100% of patients after an average follow-up of 43 months, and the average rate of wear, 0.9 mm/year.

In our study, the increase in glenoid depth was more frequent, more severe and occurred at a faster rate in the ''glenohumeral osteoarthritis'' group than in the ''avascular necrosis'' group. Glenoid deepening appears to begin when most of the glenoid cartilage has been destroyed. Glenoid deepening occurs after surgery for glenohumeral osteoarthritis in between 34 and 95% of patients in the literature. [5,6]; these rates are lower in case of avascular necrosis or fracture, between 18 and 25% [2,27].

To evaluate the influence of humeral head replacement, we studied preoperative and postoperative changes in lateral humeral offset. This technique excludes the effect of the size of the prosthesis, or the difference in radius of curvature between the native epiphysis and the prosthesis. The postoperative lateral humeral offset was only slightly increased (an average of +6.5%). Certain authors feel that an increase in offset is a source of overload to the joint, causing increased joint space wear, and a reduction in mobility by changing the lever arm of the deltoid and the supraspinatus [19,20,28]. The statistical analysis in our series did not show any relationship between this slight increase in offset and the clinical or radiographic progression of wear.

Certain authors in the literature prefer not to perform a glenoid replacement in case of glenohumeral osteoarthritis in young and active patients because of the increased risk of early loosening and the difficulties of revision [29,30]. In cases with healthy glenoid cartilage (four fragment fractures and avascular necrosis without glenoid cartilage damage), other authors recommend not performing glenoid replacement [31]. Sometimes the indication for humeral head replacement is made by default, when it appears dangerous or even impossible to perform glenoid replacement. This is true in cases of significant glenoid retroversion and/or when glenoid bone stock is insufficient. Thus, in cases of glenoid retroversion, certain authors [32] use asymmetric reaming, however Kelly and Norris [31] does not recommend this technique if posterior wear exceeds 1 cm. Another alternative is then not to replace the glenoid [30,31].

A recent procedure developed by Matsen et al. makes it possible to relieve problems of non-concentric or significantly retroversed glenoids without glenoid replacement. This is the so-called ''Ream & Run'' procedure which includes correction of posterior glenoid wear by assymetric reaming of the anterior glenoid [32,33]. In 2007, Clinton et al. [33] compared results after 3 years in 35 patients who underwent this procedure with those in 35 others who underwent total shoulder arthroplasty. The average age of patients was 56 years old, and all had glenohumeral osteoarthritis. The functional recovery at 3 years was similar in both groups.

Biological resurfacing techniques have been developed by several groups. The anterior glenohumeral capsule, an autogenic graft of the iliotibial band or an autologous graft of the calcaneal tendon or the lateral meniscus can be used [34,35]. The clinical results seem promising with 80% of satisfactory or excellent results after more than 2 years of follow-up [36]. The radiological follow-up in these cases shows limited and stable glenoid wear [34,36].

The main limits to this study are that it is retrospective in a small group of patients with the inclusion of patients with different etiologies and different prosthesis. The radiological measurements are dependent upon the quality and variability of pre- and postoperative X-rays, and on the control of image enlargement.

Additional studies in a larger group of patients would help further determine the role of etiology or the type of prosthesis. Longer follow-up of these patients would provide additional information on glenoid erosion in this situation.

Conclusion

This study evaluated the radiographic progression and clinical outcome of simple humeral head replacements with a follow-up of more than two years. Compared to total shoulder arthroplasty, this surgical procedure is simple and by definition prevents the risk of glenoid loosening. However, simple replacement of the humeral head entails a risk of glenoid wear. This study confirms and quantifies this wear, and its progression clearly seems to be influenced by the etiology of the disease, and thus by the condition of the glenoid cartilage. After an average follow-up of 4 years, this radiographic erosion of the glenoid does not seem to be associated with an increase in pain or a decrease in the clinical score.

Conflict of interest statement

None.

References

[1] Neer 2nd CS. Articular replacement for the humeral head. J Bone Joint Surg Am 1955;37-A:215—28.
[2] Parsch D, Lehner B, Loew M. Shoulder arthroplasty in nontraumatic osteonecrosis of the humeral head. J Shoulder Elbow Surg 2003;12:226—30.
[3] Levy O, Copeland SA. Cementless surface replacement arthroplasty (Copeland CSRA) for osteoarthritis of the shoulder. J Shoulder Elbow Surg 2004;13:266—71.
[4] Pfahler M, Jena F, Neyton L, Sirveaux F, et al. Hemiarthroplasty versus total shoulder prosthesis: results of cemented glenoid components. J Shoulder Elbow Surg 2006;15:154—63.
[5] Rispoli DM, Sperling JW, Athwal GS, Schleck CD, et al. Humeral head replacement for the treatment of osteoarthritis. J Bone Joint Surg Am 2006;88:2637—44.
[6] Wirth MA, Tapscott RS, Southworth C, Rockwood Jr CA. Treatment of glenohumeral arthritis with a hemiarthroplasty: a minimum five-year follow-up outcome study. J Bone Joint Surg Am 2006;88:964—73.
[7] Bailie DS, Llinas PJ, Ellenbecker TS. Cementless humeral resurfacing arthroplasty in active patients less than fifty-five years of age. J Bone Joint Surg Am 2008;90:110—7.
[8] Feeley BT, Fealy S, Dines DM, Warren RF, et al. Hemiarthroplasty and total shoulder arthroplasty for avascular necrosis of the humeral head. J Shoulder Elbow Surg 2008;17:689—94.
[9] Dalldorf PG, Banas MP, Hicks DG, Pellegrini Jr VD. Rate of degeneration of human acetabular cartilage after hemiarthroplasty. J Bone Joint Surg Am 1995;77:877—82.

[10] Sperling JW, Cofield RH, Rowland CM. Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. J Bone Joint Surg Am 1998;80:464—73.
[11] Cruess RL. Osteonecrosis of bone. Current concepts as to etiology and pathogenesis. Clin Orthop Relat Res 1986:30—9.
[12] Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999;14:756—60.
[13] Sirveaux F, Favard L, Oudet D, Huquet D, et al. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. J Bone Joint Surg Br 2004;86:388—95.
[14] Constant CR, Gerber C, Emery RJ, Sojbjerg JO, et al. A review of the Constant score: modifications and guidelines for its use. J Shoulder Elbow Surg 2008;17:355—61.
[15] Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987:160—4.
[16] Yian EH, Ramappa AJ, Arneberg O, Gerber C. The Constant score in normal shoulders. J Shoulder Elbow Surg 2005;14:128—33.
[17] Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. J Shoulder Elbow Surg 2007;16:717—21.
[18] Jonsson E, Egund N, Kelly I, Rydholm U, et al. Cup arthroplasty of the rheumatoid shoulder. Acta Orthop Scand 1986;57:542—6.
[19] Iannotti JP, Gabriel JP, Schneck SL, Evans BG, et al. The normal glenohumeral relationships. An anatomical study of one hundred and forty shoulders. J Bone Joint Surg Am 1992;74:491—500.
[20] Parsons IM, Millett PJ, Warner JJ. Glenoid wear after shoulder hemiarthroplasty: quantitative radiographic analysis. Clin Orthop Relat Res 2004:120—5.
[21] Rhydholm U, Sjögren J. Surface replacement of the humeral head in the rheumatoid shoulder. J Shoulder Elbow Surg 1993;2:286—95.
[22] Iannotti JP, Norris TR. Influence of preoperative factors on outcome of shoulder arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am 2003;85-A:251—8.
[23] Edwards TB, Kadakia NR, Boulahia A, Kempf JF, et al. A comparison of hemiarthroplasty and total shoulder arthroplasty in the treatment of primary glenohumeral osteoarthritis: results of a multicenter study. J Shoulder Elbow Surg 2003;12:207—13.
[24] Orfaly RM, Rockwood Jr CA, Esenyel CZ, Wirth MA. Shoulder arthroplasty in cases with avascular necrosis of the humeral head. J Shoulder Elbow Surg 2007;16:S27—32.
[25] Gartsman GM, Roddey TS, Hammerman SM. Shoulder arthroplasty with or without resurfacing of the glenoid in patients who have osteoarthritis. J Bone Joint Surg Am 2000;82:26—34.
[26] Cruess RL, Kwok DC, Duc PN, Lecavalier MA, et al. The response of articular cartilage to weight-bearing against metal. A study of hemiarthroplasty of the hip in the dog. J Bone Joint Surg Br 1984;66:592—7.
[27] Hasan SS, Leith JM, Campbell B, Kapil R, et al. Characteristics of unsatisfactory shoulder arthroplasties. J Shoulder Elbow Surg 2002;11:431—41.
[28] De Leest O, Rozing PM, Rozendaal LA, Van der Helm FC. Influence of glenohumeral prosthesis geometry and placement on shoulder muscle forces. Clin Orthop Relat Res 1996: 222—33.
[29] Rodosky MW, Bigliani LU. Indications for glenoid resurfacing in shoulder arthroplasty. J Shoulder Elbow Surg 1996;5:231—48.
[30] Molé D. The glenoid component in total shoulder prostheses. In: Conférence d'enseignement de la SOFCOT. Paris: Elsevier Masson; 2005. pp. 173—94.
[31] Kelly Jr JD, Norris TR. Decision making in glenohumeral arthroplasty. J Arthroplasty 2003;18:75—82.
[32] Weldon EJI, Boorman RS, Parsons IMI, Matsen FAI. ''Ream and Run'': The principles and procedures of non-prosthetic glenoid arthroplasty with prosthetic humeral hemiarthroplasty. Tech Shoulder Elbow Surg 2004;5:76—89.
[33] Clinton J, Franta AK, Lenters TR, Mounce D, et al. Nonprosthetic glenoid arthroplasty with humeral hemiarthroplasty and total shoulder arthroplasty yield similar self-assessed outcomes in the management of comparable patients with glenohumeral arthritis. J Shoulder Elbow Surg 2007;16:534—8.
[34] Ball CM, Galatz LM, Yamaguchi K. Meniscal allograft interposition arthroplasty for the arthritic shoulder: Description of a new surgical technique. Tech Shoulder Elbow Surg 2001;2:247—54.
[35] Burkhead Jr WZ, Krishnan SG, Lin KC. Biologic resurfacing of the arthritic glenohumeral joint: Historical review and current applications. J Shoulder Elbow Surg 2007;16:S248—253.
[36] Krishnan SG, Nowinski RJ, Harrison D, Burkhead WZ. Humeral hemiarthroplasty with biologic resurfacing of the glenoid for glenohumeral arthritis. Two to fifteen-year outcomes. J Bone Joint Surg Am 2007;89:727—34.